

# ACIDIC PRECIPITATION IN ONTARIO STUDY



## A SYNOPTIC SURVEY OF THE ACIDITY OF GROUNDWATERS IN THE MUSKOKA - HALIBURTON AREA OF ONTARIO, 1980

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Gérard J. M. Raymond  
Deputy Minister

ACIDIC PRECIPITATION IN ONTARIO STUDY

A SYNOPTIC SURVEY OF THE ACIDITY  
OF GROUND WATERS IN THE  
MUSKOKA-HALIBURTON AREA OF ONTARIO, 1980

APIOS REPORT  
No. 006/82

by

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## Purpose, Scope, Sampling Criteria

The purpose of this report is primarily to document the progress of the ground-water inventory in northern Ontario and to briefly discuss the quality data and observations made in the field. Some cursory analyses and correlations of data are included in the report, but it is not the intent of the report to present exhaustive statistical analyses of data. This can be done only after larger and statistically more meaningful sample results become available.

In 1980 the Ministry carried out a synoptic survey of ground-water quality in the Muskoka-Haliburton area to determine the range of ground-water pH values, with emphasis on low values as indicators of the degree of acidification of ground water. Results from that survey indicated that approximately 12% of the wells surveyed contained waters with a field pH of less than 6.0, and that some tap waters contained high levels of copper, zinc and aluminum (Sibul & Vallery, 1982). In order to extend the data base on domestic supplies provided by the Muskoka-Haliburton survey, and to address the overall question of potability of ground water in an area where surface water is known to be acid, a similar synoptic survey was undertaken in the Sudbury area. To ensure an objective approach and to facilitate comparisons with the Muskoka-Haliburton results, the sampling criteria and general survey approach remained the same.

The study encompassed an area with a radius of approximately 80 kilometres, around the City of Sudbury (Figure 1). The most southerly point sampled was at Britt, just west of Highway No. 69. In the east, the farthest site was at Crystal Falls, a small village north and slightly east of Sturgeon Falls. The northerly limit, falling well short of the 80-kilometre radius, was at Milnet, an old, deserted logging settlement. In the west, the furthest point reached was at Birch Lake (formerly Gough Lake), which is several kilometres northwest of Espanola.

The intent of the synoptic survey was to sample ground waters from as many geologic environments and well depths as possible, excluding waters that might be contaminated by land development-related



activities such as septic systems, road salting, etc. The following main points formed the sampling criteria in the Sudbury area:

1. sample in Precambrian Shield areas only, both in overburden and bedrock, and in shallow and deep wells;
2. whenever possible, sample wells for which there are Ministry water-well records; for those wells without records, site-specific geologic notes and well construction details are to be made;
3. avoid sampling in towns, villages, and other built-up areas, as well as very close to roads that might have chemicals applied to them for ice or dust control;
4. obtain samples directly from house taps; if possible, avoid sampling treated water;
5. field test each sample for pH, conductivity and water temperature; obtain samples for lab analyses when field pHs are less than 6.0; in addition, take approximately every fifth sample for lab analysis, regardless of field pH;
6. lab samples are to be analyzed for the following: sodium, potassium, calcium, magnesium, iron, manganese, sulphate, chloride, nitrate, alkalinity, hardness and conductivity; when pH is less than 6.0, analyze also for aluminum, arsenic, barium, cadmium, chromium, copper, lead and zinc.

Three generally separate sampling runs were made, each for a different purpose. The initial run was to obtain field pH, conductivity and water temperature values, as well as to take water samples for lab analysis. A second run was necessary to check questionable field data and take duplicate water samples, and a third run consisted of sampling predesignated sites for determination of trace metals derived from domestic plumbing systems.

Two instruments were used in the field, a pH meter - "PHM 80 Portable pH Meter" with accompanying glass electrode, and a conductivity meter - "YSI Model 33 S-C-T Meter", with accompanying probe. Both instruments proved to be convenient, reliable and suitable for a field survey of this type.

#### Distribution of Field Conductivity and pH Values

The synoptic survey consisted of sampling at 123 domestic well sites and at two ground-water municipal supply sites (Capreol and Hanmer). Of the 123 domestic well sites, ground water was obtained from 81 overburden wells, from 36 bedrock wells and from 6 wells where the source of water was unknown. The municipal supplies at Capreol and Hanmer derive ground water from overburden. At 42 of the sites, a total of 44 samples were taken for lab analyses of the common inorganic parameters mentioned earlier. At all sites the samples were collected from house taps after 2-3 minutes of flushing.

Figure 2 shows the geographical distribution of field conductivity readings obtained in the initial run in the survey. Conductivity readings for duplicate samples vary slightly and are not used in the figure. Of the 121 samples for which conductivity readings were taken in the initial run (see Appendix), only 4 samples had values greater than 1000 umhos/cm; 26 samples had values between 500-1000 umhos/cm; the majority of values (84 samples) were between 100-500 umhos/cm. Seven samples had values of less than 100 umhos/cm and their distribution appears to be sporadic within the sampling area.

Figure 3 shows the geographical distribution of all field pH readings obtained in the initial run in the survey. On the basis of the pH ranges shown, clear patterns are not obvious; however, it appears that pH values between 6-7 dominate southwest of Sudbury towards Espanola. Only 5% of the samples had pH values less than 6.0, with the largest percentage (52%) of the samples having pH values greater than 7.0 (Table 1). It is important to note that these statistics apply to one-time sample results in the initial run. Duplicate samples taken in subsequent runs changed the



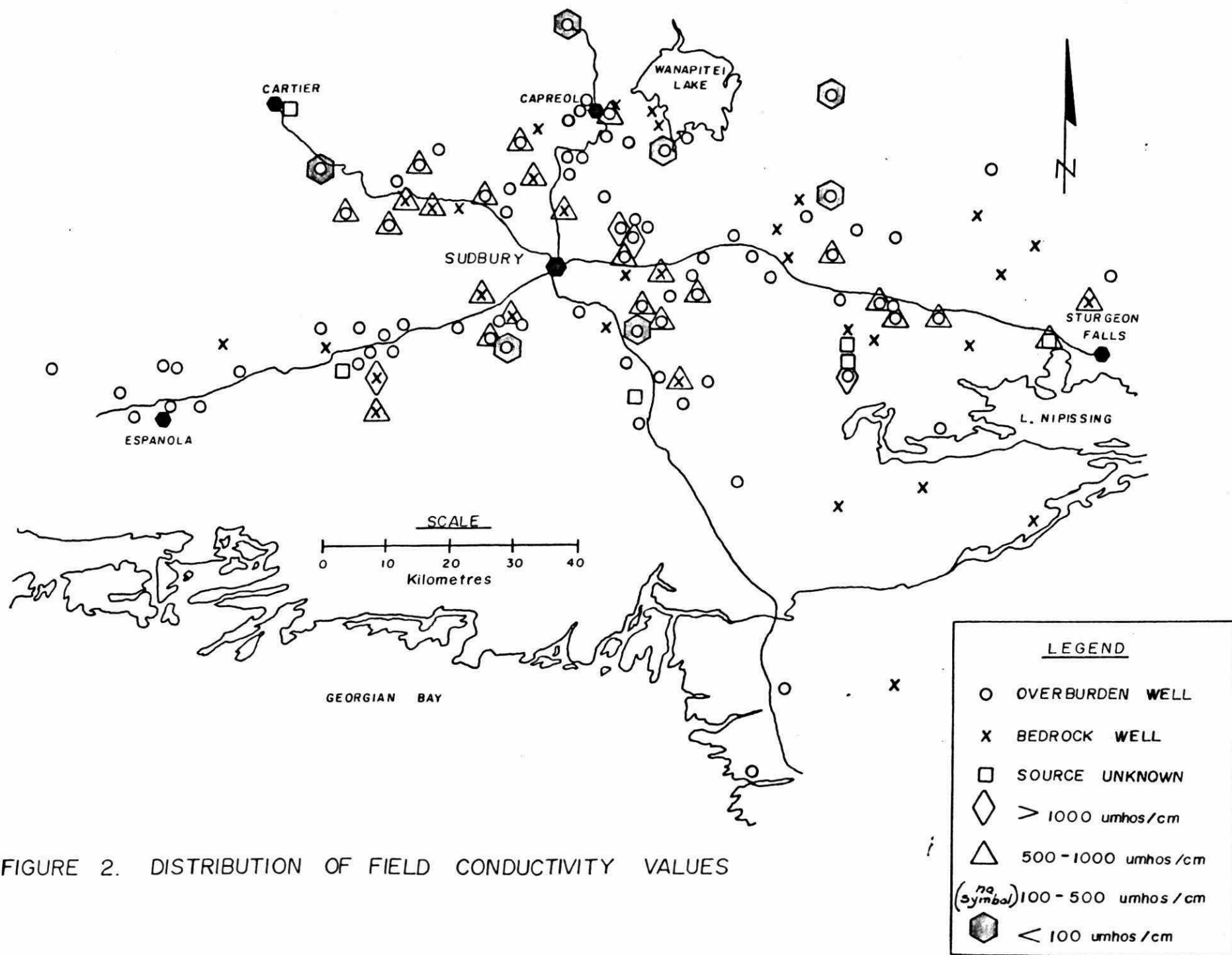


FIGURE 2. DISTRIBUTION OF FIELD CONDUCTIVITY VALUES

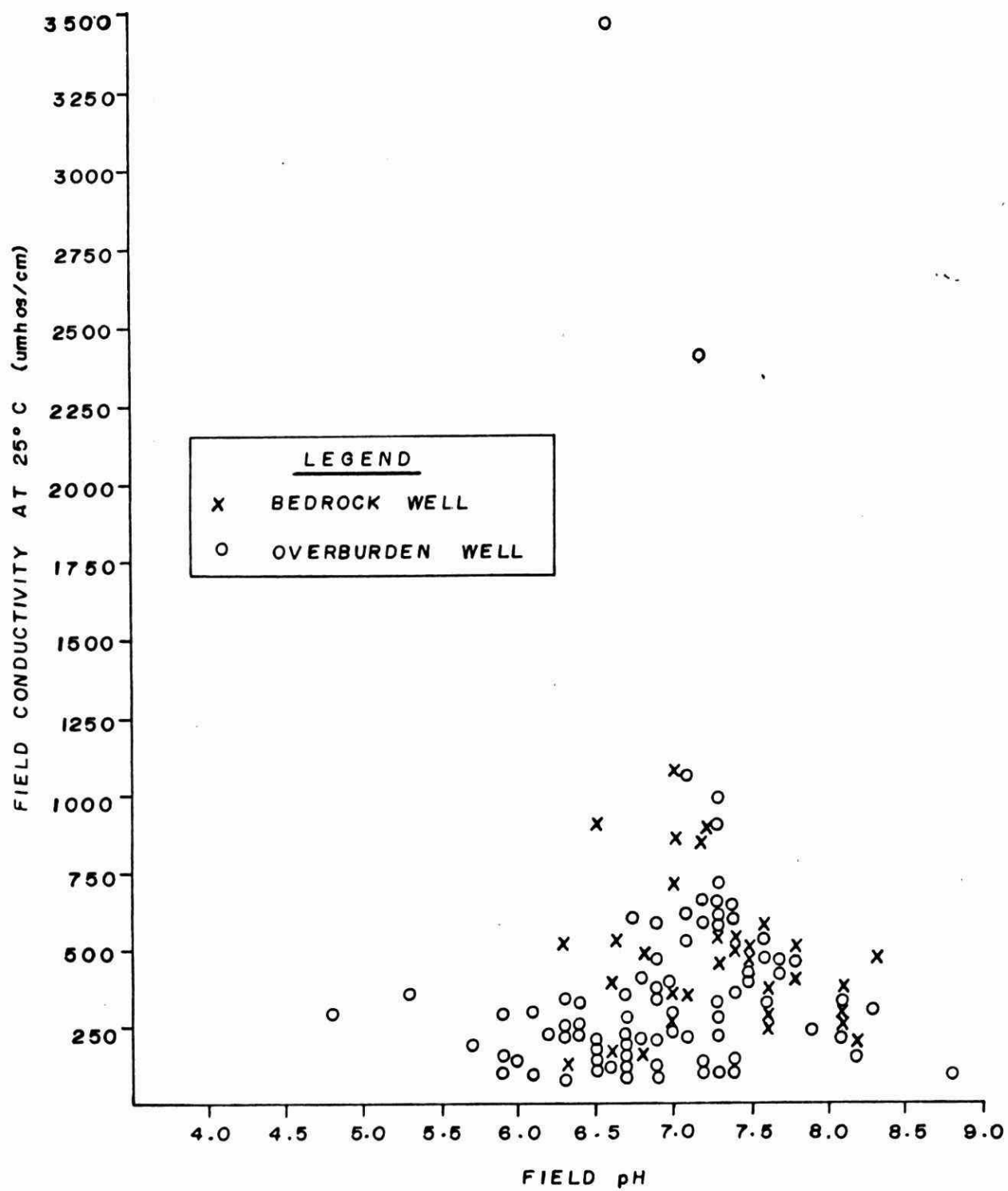


FIGURE 3. FIELD CONDUCTIVITY AND FIELD pH

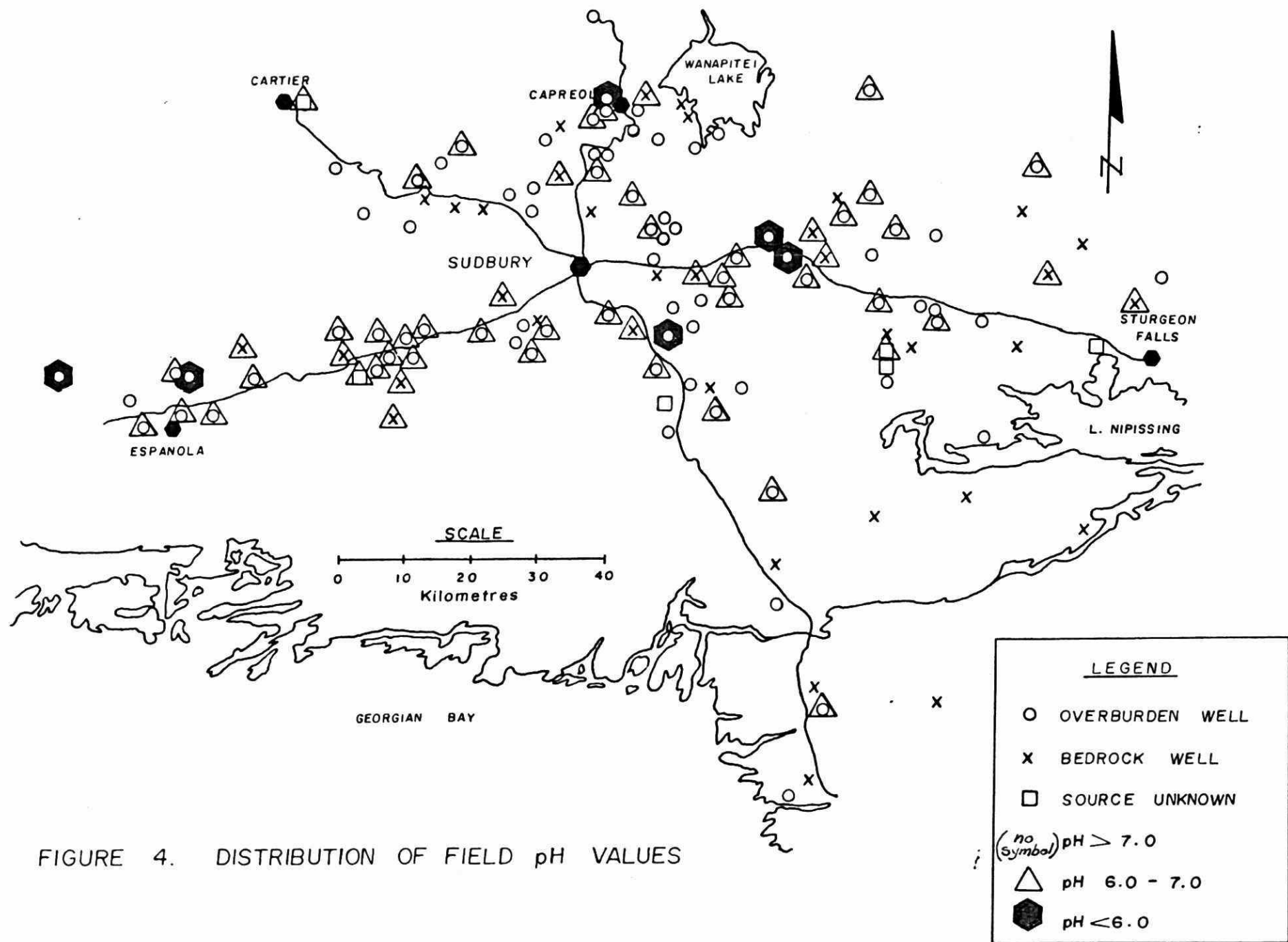


FIGURE 4. DISTRIBUTION OF FIELD pH VALUES

statistics only slightly. For example, the pH of sample 85 taken in the initial run in September 1981 was 6.1, whereas the duplicate sample taken in November 1981 had a pH of 5.8. Similarly, a sample taken at site 47 had a pH of 6.1 in September and a pH of 5.0 in another sample in November 1981. These examples, substantiated to a large degree by a year and a half of pH monitoring data in the Muskoka area, show that pH values vary during the year. These variations can be large and consequently one-time sampling statistics may be misleading and should be used with care in discussing ground-water acidity.

Table 1. Range of ground-water pH values

pH	No. of Samples	Percent
$\leq 6.0$	6	5
6.0-7.0	54	43
$\geq 7.0$	65	52
TOTALS:	125	100

There appears to be generally a poor correlation of field pH and conductivity values (Figure 4). All pH values less than 6.0 occurred in ground waters obtained from shallow wells in overburden (Figure 5, Table 2). The average depth among the six shallow wells is 5.8 metres. The shallowest well is 4.5 metres; the deepest is 6.7 metres, a relatively small range of well depths. Five of the six wells are completed in sand/gravel, while the sixth well is reportedly completed in organic peat and muck, but likely also obtains water from sand and/or gravel.

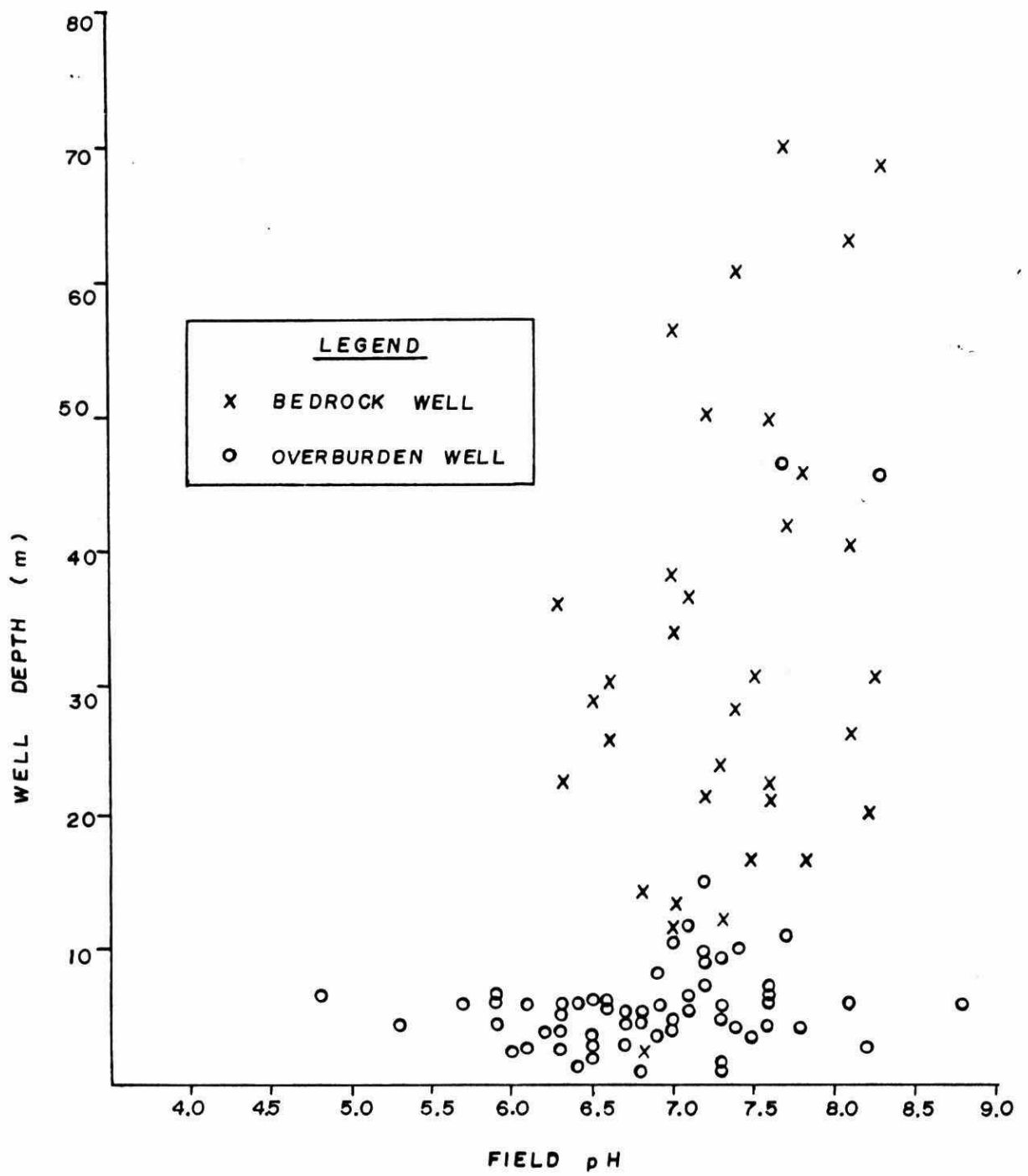


FIGURE 5. WELL DEPTH AND FIELD pH

Table 2. Ground waters with pH less than 6.0

Site No.	pH	Conductivity (umhos/cm)	Well Depth (m)	Type of Overburden
9	5.9	167	4.5	Sand
10	5.9	295	6.7	Peat, Muck
34	4.8	270	6.7	Sand, Gravel
41	5.7	180	6.1	Sand
43	5.3	355	4.5	Sand
56	5.9	81	6.1	Sand, Gravel

For double checking, the well yielding the lowest pH value of 4.8 at Capreol north of Sudbury was sampled twice. The results are as follows:

Sample No.	Date of Sampling	pH	Conductivity (umhos/cm)
34(1)	Aug. 14, 1981	4.8	270
34(2)	Sept. 30, 1981	4.9	197

Although the two pH readings are virtually identical, the conductivity readings vary; the reason for this is not known. The well is 6.7 metres deep and is completed in sand and gravel. It was not possible to check the quality of ground water in other wells in the area because all nearby houses are on the Capreol municipal ground-water supply. Two tap water samples of the Capreol municipal water have a pH of 6.7 and 7.2.

### Inorganic Water Quality

A total of 44 samples (from 42 wells) were taken for analyses of the common inorganic parameters shown in Table 3. Duplicate samples were taken at sites 34 and 70; sample 34(2) was taken to validate the first sample, 34(1), and the two samples at site 70 represent one sample, 70(2), taken before the softener and the other, 70(1), after the softener. As apparent from the high hardness value in 70(1), the softener was not functioning and appears to be contributing large quantities of sodium and chloride to the water.

In spite of efforts to avoid sampling contaminated wells, chloride contamination is suspected in a number of wells, and this became apparent only after the samples were taken and analysed in the lab.

Data in Table 3 show a wide variation in water quality as evidenced by a wide range in the conductivity values (76 umhos to 3465 umhos). A cursory examination of data in the table indicates the following:

- two samples, 34(1) and 43, have nitrate concentrations above the drinking water objective of 10 mg/L and a field inspection of both sites did not reveal obvious sources of contamination. Coincidentally, both samples have pH values of less than 6.0 and lab alkalinities for both are less than 10 mg/L;
- numerous samples have noticeably high chloride values, possibly due to contamination from road salt. Samples from two sites are particularly notable - sites 69 and 70. The sample at site 69 contains 534 mg/L chloride, and sample 70(2) contained 246 mg/L. Both wells are adjacent to the same highway that is salted during the winter;
- all the samples with pH values of less than 6.0 also have low alkalinity values, and the lowest pH value of 4.8 at Capreol also has the lowest alkalinity value of 1.0 mg/L. This cursory correlation suggests that in at least the above-mentioned cases, the buffering capacities of the soil or rock media are very low, and that lower pH values can be expected with time.

TABLE 3: INORGANIC ANALYSES, APIOS GROUND-WATER INVENTORY, 1981

Sample No.	Location Township Con/Lot	Date	pH	Sodium	Potas- sium	Calcium	Magnes- ium	Bicar- bonate	Sulphate	Chloride	Nitrate	Iron	Manganese	Alkalin- ity	Hardness	Conductivity umhos/cm
			Field Lab	mg/L Na	mg/L K	mg/L Ca	mg/L Mg	mg/L HCO <sub>3</sub>	mg/L SO <sub>4</sub>	mg/L Cl	mg/L N	mg/L Fe	mg/L M	mg/L CaCO <sub>3</sub>	mg/L CaCO <sub>3</sub>	Field Lab
Drinking Water Objectives (mg/L)									250	250	10	0.3	0.05			
<u>Nipissing District</u>																
24.	Field Tp. C1/L2	06/08/81	8.2 7.7	1.7	.30	18.6	5.15	82.9	9.0	.30	.010	.04	.002	68	68	151 149
121.	Gibbons Tp. C2/L12	08/10/81	8.1 7.9	14.5	4.0	43.0	12.0	162.2	47.0	7.0	5.7	.02	.010	133	158	364 360
<u>Parry Sound District</u>																
1.	Henvey Tp. C1/L8	05/08/81	7.7 7.2	6.6	1.70	41.0	7.00	208.6	29.0	1.10	.080	.36	.450	171	131	- 380
87.	Mowat Tp. C11/L30	22/09/81	6.7 7.4	3.0	1.2	54.0	8.0	186.6	29.0	0	1.1	5.30	.006	153	168	329 345
126.	Dokis Reserve L45B	08/10/81	8.2 8.0	3.0	1.9	26.0	5.0	86.6	22.0	0	0	.01	.016	71	85	178 182
<u>Sudbury District</u>																
6.	Burwash Tp. C4/L11	05/08/81	7.2 6.3	2.4	3.30	10.2	1.80	14.6	17.0	3.65	3.10	.34	.022	12	33	105 106
8.	Dryden Tp. C4/L4	06/08/81	6.3 6.4	10.1	1.40	28.0	17.5	113.4	46.5	25.00	1.00	.18	.012	93	142	335 350
9.	Awrey Tp. C6/L8	06/08/81	5.9 6.2	9.5	2.00	11.8	2.15	20.7	21.5	16.00	1.70	.04	.030	17	38	167 146
10.	Awrey Tp. C5/L3	06/08/81	5.9 6.1	19.0	2.25	22.0	4.35	48.8	32.0	40.50	1.50	.04	.008	40	73	295 290
32.	Valley East (Capreol) Tp. C3/L9	13/08/81	8.8 6.2	1.5	.50	17.0	2.0	43.9	16.0	2.0	0	.03	.004	36	50	118 104
34(1)	Norman Tp. C1/L11	14/08/81	4.8 4.7	16.0	5.1	18.0	4.0	1.22	29.0	20.0	15.0	.03	.400	1	64	270 270
34(2)	Norman Tp. C1/L11	30/09/81	4.9 7.3	10.0	4.6	15.0	3.0	3.66	30.0	11.0	8.8	.04	.740	3	50	197 202



TABLE 3: Cont'd

Sample No.	Location Township Con/Lot	Date	pH Field Lab	Sodium mg/L Na	Potas- sium mg/L K	Calcium mg/L Ca	Magnes- ium mg/L Mg	Bicar- bonate mg/L HCO <sub>3</sub>	Sulphate mg/L SO <sub>4</sub>	Chloride mg/L Cl	Nitrate mg/L N	Iron mg/L Fe	Manganese mg/L M	Alkalini- ty mg/L CaCO <sub>3</sub>	Hardness mg/L CaCO <sub>3</sub>	Conductivity umhos/cm Field Lab
Drinking Water Objectives (mg/L)									250	250	10	0.3	0.05			
35.	Valley East (Capreol) Tp. C6/L6	14/08/81	7.0 6.2	7.5	1.4	37.0	5.0	120.7	24.0	8.0	0	.28	.082	99	114	260 250
38.	Valley East (Hanmer) Tp. C1/L12	14/08/81	7.2 6.6	4.0	.90	104.0	26.0	378.2	57.0	2.0	0	11.25	.480	310	366	651 610
41.	Baldwin Tp. C4/L6	17/08/81	5.7 6.9	7.0	2.9	16.0	4.0	13.4	14.0	20.0	4.8	.02	.052	11	57	180 175
43.	Gough Tp. C4/L4	17/08/81	5.3 6.4	9.0	11.8	11.0	5.0	6.1	19.0	10.0	14.3	.27	.276	5	49	355 227
47.	Waters Tp. C1/L3	18/08/81	6.1 7.3	2.0	1.2	8.0	2.0	7.3	18.0	7.0	.10	.06	.060	6	28	87 87
50.	Burwash Tp. C1/L5	19/08/81	6.8 7.2	8.0	1.6	15.0	10.0	78.0	23.0	6.0	.30	3.50	.014	64	80	193 175
55.	Cleland Tp. C3/L9	19/08/81	7.3 7.3	16.5	1.6	80.0	29.0	392.8	24.0	6.0	.10	.08	.006	322	318	602 610
59.	Cleland Tp. C6/L2	20/08/81	6.8 7.4	11.5	1.6	102.0	22.0	374.5	32.0	24.0	.40	.05	.022	307	348	602 670
61.	Dryden Tp. C3/L10	20/08/81	6.6 7.4	12.0	2.0	58.0	22.0	139.0	60.0	65.0	.10	.03	.028	114	236	542 520
62.	Louise Tp. C6/L1	09/09/81	6.0 6.1	8.0	2.2	11.0	4.0	31.7	25.0	12.0	.30	.61	.016	26	45	135 140
66.	Valley East (Bleazard) Tp. C4/L9	10/09/81	7.0 7.2	210.0	1.0	1.0	0	342.8	56.0	83.0	0	.09	.016	281	4	861 860
67.	Rayside Tp. C4/L8	10/09/81	7.4 7.3	3.0	.20	101.0	29.0	347.7	84.0	4.0	.90	.02	.002	285	372	635 680
69.	Neelon & Garson (Neelon) Tp. C5/L3	11/09/81	7.2 6.8	129.0	1.60	240.0	83.0	423.3	81.0	534.0	0	.07	.030	347	940	2410 2400
70(1)	Neelon & Garson (Neelon) Tp. C6/L4	11/09/81	6.6 6.7	500.0	5.2	140.0	39.0	280.6	75.0	880.0	4.2	.03	2.25	230	510	3465 3300

TABLE 3: Cont'd

Sample No.	Location Township Con/Lot	Date	pH Field Lab	Sodium mg/L Na	Potas- sium mg/L K	Calcium mg/L Ca	Magnes- ium mg/L Mg	Bicar- bonate mg/L HCO <sub>3</sub>	Sulphate mg/L SO <sub>4</sub>	Chloride mg/L Cl	Nitrate mg/L N	Iron mg/L Fe	Manganese mg/L M	Alkalin- ity mg/L CaCO <sub>3</sub>	Hardness mg/L CaCO <sub>3</sub>	Conductivity umhos/cm Field Lab
Drinking Water Objectives (mg/L)									250	250	10	0.3	0.05			
70(2)	Neelon&Garson (Neelon) Tp. C6/L4	15/09/81	6.8 7.0	66.5	22.5	136.0	39.0	283.0	67.0	246.0	1.9	.05	1.24	232	500	1386 1360
74.	Morgan Tp. C2/L5	14/09/81	6.7 6.8	3.5	.70	18.0	5.0	63.4	21.0	0	.20	.80	.150	52	65	145 149
77.	Balfour Tp. C2/L8	14/09/81	7.2 7.2	15.5	3.3	109.0	30.0	342.8	45.0	80.0	.10	4.60	.256	281	336	844 830
80.	MacLennan Tp. C6/L5	16/09/81	7.1 7.2	10.5	1.3	25.0	4.0	42.7	24.0	29.0	.70	.15	.044	35	78	199 225
85.	Baldwin Tp. C8/L1	17/09/81	6.1 6.4	33.5	8.4	20.0	4.0	37.8	54.0	25.0	4.9	.38	.028	31	66	303 329
86.	Hallam Tp. C6/L5	17/09/81	6.9 6.8	4.5	.6	26.0	7.0	74.4	19.0	15.0	.80	.05	.004	61	93	201 210
89.	Hutton Tp. C3/L2	23/09/81	7.2 6.8	2.0	.90	12.0	2.0	43.9	13.0	0	0	.16	.044	36	40	99 94
90.	Valley East (Blezard) Tp. C2/L4	24/09/81	7.6 7.5	11.0	3.9	66.0	22.0	212.2	92.0	17.0	0	.63	.168	174	258	542 550
92.	Valley East (Capreol) Tp. C2/L12	24/09/81	8.1 7.8	2.5	.50	32.0	4.0	74.4	34.0	4.0	1.0	.03	.004	61	96	209 218
93.	Valley East (Capreol) Tp. C2/L5	24/09/81	7.6 7.6	3.5	1.8	64.0	21.0	283.0	29.0	0	0	.30	.166	232	248	461 472
95.	Waters Tp. C5/L10	29/09/81	6.3 6.9	32.5	1.9	65.0	5.0	87.8	61.0	80.0	.40	.04	.060	72	182	514 530
97.	Drury, Denison & Graham (Graham) Tp. C2/L11	29/09/81	6.3 6.8	14.0	3.5	25.0	4.0	41.4	25.0	38.0	.20	.02	.004	34	80	257 279

TABLE 3: Cont'd

Sample No.	Location Township Con/Lot	Date	pH		Sodium	Potas- sium	Calcium	Magnes- ium	Bicar- bonate	Sulphate	Chloride	Nitrate	Iron	Manganese	Alkalin- ity	Hardness	Conductivity umhos/cm	
			Field	Lab	mg/L Na	mg/L K	mg/L Ca	mg/L Mg	mg/L HCO <sub>3</sub>	mg/L SO <sub>4</sub>	mg/L Cl	mg/L N	mg/L Fe	mg/L M	mg/L CaCO <sub>3</sub>	mg/L CaCO <sub>3</sub>	Field	Lab
Drinking Water Objectives (mg/L)										250	250	10	0.3	0.05				
100.	Norman Tp. C1/L12	30/09/81	6.7	6.9	7.0	1.6	22.0	5.0	58.5	22.0	15.0	.20	.18	.004	48	78	189	200
112.	Loughrin Tp. C3/L2	06/10/81	6.9	8.2	2.0	.80	10.0	1.0	24.4	16.0	0	0	.08	.004	20	31	76	80
114.	Dowling (Fairbank) Tp. C6/L3	07/10/81	7.3	7.3	22.5	2.1	78.0	25.0	236.6	98.0	38.0	0	3.25	1.160	194	300	652	650
115.	Dowling Tp. C3/L1	07/10/81	7.2	7.4	13.5	2.1	125.0	42.0	578.2	24.0	16.0	.50	.05	.052	474	484	882	890
118.	Cascaden Tp. C5/L2	07/10/81	7.3	7.4	3.5	.70	12.0	2.0	35.3	14.0	3.0	0	.01	.002	29	38	90	100
119.	Cartier Tp. C5/L10	07/10/81	6.2	6.7	61.0	3.5	10.0	1.0	51.2	27.0	61.0	.10	.01	.184	42	29	377	405

NOTE: The differences between field and lab pHs are attributed generally to slight water quality changes between the time of analysis in the field and in the lab; the field pHs are assumed to be more accurate.

The relatively wide variability of ground-water chemistry is further displayed by the scatter of points shown on Figure 6. The scatter of points in the central, diamond-shaped diagram, which reflects the total anion and cation chemistry of the samples, is due to the larger variability of anions (shown on the right-hand triangle) than the cations (on the left-hand triangle). The majority of waters show a predominance of  $\text{HCO}_3$  and these are usually accepted in hydrogeology to be the youngest waters; progressively older waters are indicated by the predominance of  $\text{SO}_4$  and  $\text{Cl}$  ions, although at least some of the high chloride waters likely indicate contamination rather than age.

### Trace Metals

Samples from the 42 wells analysed for the common inorganic parameters were also analysed for the trace metals of aluminum, arsenic, barium, cadmium, chromium, copper, lead and zinc (Table 4). A second set of trace metal samples was taken subsequently to determine the effects of plumbing systems on trace metal contents in domestic ground-water supplies (Table 5). Except for one system that was reported to contain plastic piping only (No. 47), all other systems were reported to contain copper plumbing. The sampling strategy for trace metals at this stage of the investigation was to obtain only one additional sample rather than to take repetitive samples to define possible variations in metal levels at specific sites.

The results shown in Table 4 are assumed to be indicative of background levels of trace metals in ground water because the samples were taken after a suitable period of flushing to obtain samples of ground water unaffected by plumbing systems.

With a few exceptions, results indicate generally low background levels of most trace metals. Arsenic, cadmium and chromium are consistently low, while levels of the other metals vary considerably but all are usually well below the drinking water objectives. Aluminum, copper and zinc levels in a few samples are noteworthy because the levels are well above those in the majority of samples.

# LEGEND

○ - overburden well

x - bedrock well

● - circles denote samples having a pH of less than 6.0

all values in percent equivalents per million

FIGURE 6. MAJOR - ION CHEMISTRY

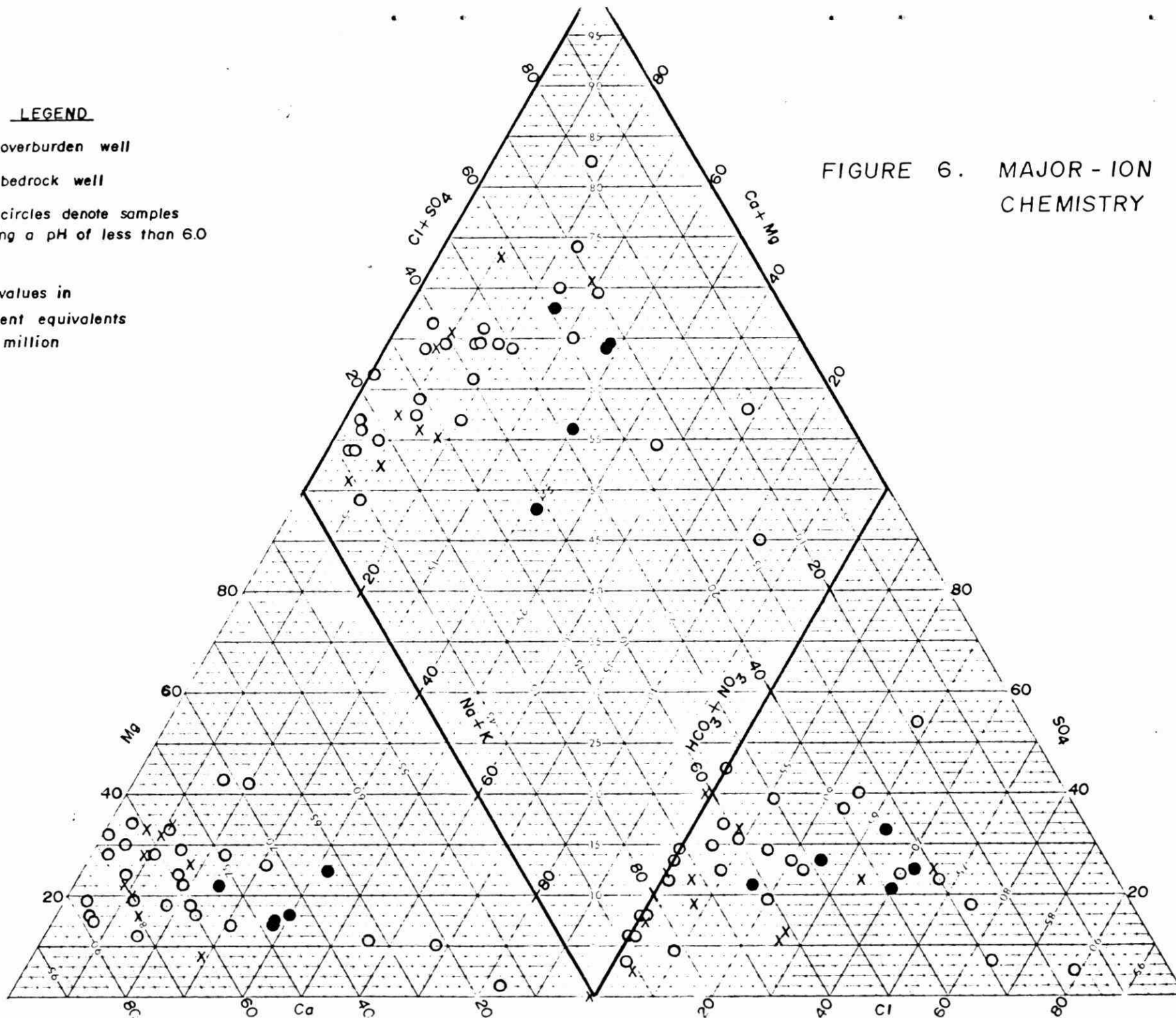


TABLE 4. TRACE METALS ANALYSES, APIOS GROUND-WATER INVENTORY, 1981

Sample No.	Location Township Con/Lot	Date	pH Field		Aluminum mg/L Al	Arsenic mg/L As	Barium mg/L Ba	Cadmium mg/L Cd	Chromium mg/L Cr	Copper mg/L Cu	Lead mg/L Pb	Zinc mg/L Zn	S.I.* @25°C
Drinking Water Objectives (mg/L)					NA	0.05	1.0	0.01	0.05	1.0	0.05	5.0	
Nipissing District													
24.	Field Tp. C1/L2	06/08/81	8.2	7.7	.034	.001	.004	.0001	.002	.003	.003	.012	-0.20
121.	Gibbons Tp. C2/L12	08/10/81	8.1	7.9	.058	< .001	.009	.0002	< .001	.002	< .003	< .001	+0.40
Parry Sound District													
1.	Henvey Tp.C1/L8	05/08/81	7.7	7.2	.054	< .001	.110	.0003	.003	.083	.006	.270	+0.10
87.	Mowat Tp. C11/L30	22/09/81	6.7	7.4	.058	< .001	.022	.0002	.002	.017	.003	.074	-0.86
126.	Dokis Reserve L45B	08/10/81	8.2	8.0	.039	< .001	.032	.0001	.001	.004	<.003	.016	0
Sudbury District													
6.	Burwash Tp.C4/L11	05/08/81	7.2	6.3	.079	< .001	.033	.0002	< .001	.270	.005	.060	-2.55
8.	Dryden Tp. C4/L4	06/08/81	6.3	6.4	.094	< .001	.022	< .0001	.002	.049	< .003	.130	-1.75
9.	Awrey Tp. C6/L8	06/08/81	5.9	6.2	.041	< .001	.069	< .0001	< .001	.140	.009	.041	-3.40
10.	Awrey Tp. C5/L3	06/08/81	5.9	6.1	.054	.001	.046	.0002	.001	.920	.016	1.300	-2.40
32.	Valley East (Capreol) Tp. C3/L9	13/08/81	8.8	6.2	.005	< .001	.006	< .0001	.001	.002	< .003	.044	+0.10
34(1)	Norman Tp. C1/L11	14/08/81	4.8	4.7	3.200	.001	.190	.0018	.006	.039	< .003	.310	N.A.

\* S.I. = Langelier Saturation Index; see text on page 23

TABLE 4. Cont'd

Sample No.	Location Township Con/Lot	Date	pH		Aluminum	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Zinc	S.I.* @25°C	
			Field	Lab	mg/L Al	mg/L As	mg/L Ba	mg/L Cd	mg/L Cr	mg/L Cu	mg/L Pb	mg/L Zn		
Drinking Water Objectives (mg/L)						NA	0.05	1.0	0.01	0.05	1.0	0.05	5.0	
34(2)	Norman Tp. C1/L11	30/09/81	4.9	7.3	1.600	< .001	.110	.0005	.003	.050	< .003	.230	N.A.	
35.	Valley East (Capreol) Tp. C6/L6	14/08/81	7.0	6.2	.092	.001	.010	.0002	.002	.045	.006	.220	-0.90	
38.	Valley East (Hanmer) Tp. C1/L12	14/08/81	7.2	6.6	.132	.001	.112	.0002	.009	.021	.008	.047	+0.30	
41.	Baldwin Tp. C4/L6	17/08/81	5.7	6.9	.467	< .001	.048	.0002	< .001	.008	.003	.028	-3.70	
43.	Gough Tp. C4/L4	17/08/81	5.3	6.4	.521	< .001	.258	.0002	.001	.002	< .003	.656	N.A.	
47.	Waters Tp. C1/L3	18/08/81	6.1	7.3	.213	< .001	.051	.0005	< .001	.058	.013	.140	N.A.	
50.	Burwash Tp. C1/L5	19/08/81	6.8	7.2	-	< .001	NOT ANALYSED FOR THESE PARAMETERS				-	-	-1.70	
55.	Cleland Tp. C3/L9	19/08/81	7.3	7.3	.140	< .001	.058	.0017	.003	.019	.005	.180	+0.25	
59.	Cleland Tp. C6/L2	20/08/81	6.8	7.4	.150	< .001	.039	.0019	.004	.065	< .003	.240	-0.15	
61.	Dryden Tp. C3/L10	20/08/81	6.6	7.4	.110	< .001	.044	.0038	.003	.050	< .003	.210	-1.05	
62.	Louise Tp. C6/L1	09/09/81	6.0	6.1	.039	< .001	.024	.001	< .001	.026	.004	.004	-3.10	
66.	Valley East (Bleazard) Tp. C4/L9	10/09/81	7.0	7.2	.006	< .001	.002	.0013	< .001	.021	.004	.059	-2.05	

\* S.I. = Langelier Saturation Index; see text on page 23

TABLE 4. Cont'd

Sample No.	Location Township Con/Lot	Date	pH		Aluminum mg/L Al	Arsenic mg/L As	Barium mg/L Ba	Cadmium mg/L Cd	Chromium mg/L Cr	Copper mg/L Cu	Lead mg/L Pb	Zinc mg/L Zn	S.I.* @25°C
			Field	Lab									
Drinking Water Objectives (mg/L)					NA	0.05	1.0	0.01	0.05	1.0	0.05	5.0	
67.	Rayside Tp. C4/L8	10/09/81	7.4	7.3	.130	<.001	.008	.0002	.006	.051	.005	.630	+0.40
69.	Neelon & Garson (Neelon) Tp. C5/L3	11/09/81	7.2	6.8	.320	<.001	.140	.0003	.008	.017	<.003	.250	+0.66
70(1)	Neelon & Garson (Neelon) Tp.C6/L4	11/09/81	6.6	6.7	.200	<.001	.037	<.0001	.003	.020	<.003	.034	-0.35
70(2)	Neelon & Garson (Neelon) Tp.C6/L4	15/09/81	6.8	7.0	.260	<.001	.120	.0005	.009	.035	.004	.017	-0.15
74.	Morgan Tp. C2/L5	14/09/81	6.7	6.8	.034	<.001	.015	.0003	.002	.038	<.003	.010	-1.80
77.	Balfour Tp. C2/L8	14/09/81	7.2	7.2	.180	.004	.052	.0004	.007	.008	<.003	.005	+0.24
80.	MacLennan Tp. C6/L5	16/09/81	7.1	7.2	.034	<.001	.022	.0002	.001	.210	.004	.250	-1.42
85.	Baldwin Tp. C8/L1	17/09/81	6.1	6.4	.120	<.001	.027	.0002	.002	.510	.006	.003	-2.60
86.	Hallam Tp. C6/L5	17/09/81	6.9	6.8	.036	<.001	.005	.0001	.002	.065	.003	.230	-1.35
89.	Hutton Tp. C3/L2	23/09/81	7.2	6.8	.016	<.001	.015	.005	<.001	.002	.011	2.800	-1.65
90.	Valley East (Blezard)Tp.C2/L4	24/09/81	7.6	7.5	.072	.001	.009	<.0001	.003	.004	.004	.011	+0.20
92.	Valley East (Capreol)Tp.C2/L12	24/09/81	8.1	7.8	.015	<.001	.006	.0002	.002	.003	.004	.021	-0.05

\* S.I. = Langelier Saturation Index; see text on page 23



TABLE 4. Cont'd

Sample No.	Location Township Con/Lot	Date	pH		Aluminum mg/L Al	Arsenic mg/L As	Barium mg/L Ba	Cadmium mg/L Cd	Chromium mg/L Cr	Copper mg/L Cu	Lead mg/L Pb	Zinc mg/L Zn	S.I.* @25°C
			Field	Lab									
Drinking Water Objectives (mg/L)					NA	0.05	1.0	0.01	0.05	1.0	0.05	5.0	
93.	Valley East (Capreol) Tp. C2/L5	24/09/81	7.6	7.6	.059	.001	.035	.0002	.003	.004	.004	.180	+0.3
95.	Waters Tp. C5/L10	29/09/81	6.3	6.9	.045	< .001	.018	.0003	< .001	.230	.006	.320	-1.55
97.	Drury, Denison & Graham (Graham) Tp. C2/L11	29/09/81	6.3	6.8	-	< .001	NOT ANALYSED FOR THESE PARAMETERS				-	-	-2.25
100.	Norman Tp. C1/L12	30/09/81	6.7	6.9	.220	< .001	.020	.0003	.002	.540	.008	.020	-1.75
112.	Loughrin Tp. C3/L2	06/10/81	6.9	8.2	.017	< .001	.004	< .0001	< .001	.023	< .003	.490	-2.40
114.	Dowling (Fairbank) Tp. C6/L3	07/10/81	7.3	7.3	.140	.009	.056	< .0001	.007	.008	< .003	.110	+0.03
115.	Dowling Tp. C3/L1	07/10/81	7.2	7.4	.230	.001	.039	< .0001	.006	.089	< .003	.071	+0.45
118.	Cascaden Tp. C5/L2	07/10/81	7.3	7.4	.022	< .001	.003	< .0001	.001	< .001	< .003	< .001	-1.67
119.	Cartier Tp. C5/L10	07/10/81	6.2	6.7	.022	< .001	.037	.0001	< .001	.031	.005	.025	-2.65

\* S.I. = Langelier Saturation Index; see text on page 23

The large aluminum concentrations of 3.2 and 1.6 mg/L in samples 34(1) and 34(2), respectively, are most notable, while concentrations in the other low-pH samples, 41 and 43, are considerably above the concentrations in most of the other samples. The remaining low-pH samples, 9 and 10, do not have notably high aluminum values (0.041 and 0.054 mg/L, respectively).

The highest copper value of 0.92 mg/L in sample 10 is just below the drinking water objective of 1.0 mg/L, while copper levels in the other four low-pH samples are considerably less and generally close to background levels.

Zinc levels above 1.0 mg/L are found in samples 10 and 89, although subsequent sampling of flushed cold water at site 10 has a zinc content of only 0.45 mg/L. The reason for the 2.8 mg/L concentration of zinc in sample 89 (pH = 7.2) is not obvious but may be related to the fact that the sample was obtained from a shallow well equipped with a hand pump used by summer residents only.

In all of the above discussions it is important to keep in mind that the results in Table 4 represent only one sample at a particular time of the year and that large variations in trace metal contents may occur with time.

Each sampling of tap water to determine trace metals content due to possible leaching of metals from a household plumbing system consisted of four samples:

- I. a sample from the hot water system with no previous flushing;
- II. a sample from the cold water system with no previous flushing;
- III. a sample from the hot water system after several minutes of flushing;

IV. a sample from the cold water system after several minutes of flushing.

The four sets of samples were obtained from four wells that had pH values of less than 6.0 in the initial sampling run, and from five other wells having waters with variable pHs.

In most cases the unflushed samples were obtained from taps in the morning, representing water left standing in the pipes throughout the night. The hot, flushed samples were obtained after sufficient flushing to obtain hot water samples. Subsequent flushing of cold water was carried out long enough to get samples deemed representative of water in the wells.

Although some of the trace metals such as arsenic and barium are generally not expected to be present in domestic plumbing systems, they were analysed for and are tabled in this report to indicate background levels in ground water.

Results of the analyses of trace metals in this investigation are shown in Table 5. Also included in the table are the Langelier saturation indices (S.I.), which indicate generally the corrosiveness of waters; the index is calculated as follows:

$$\begin{aligned} \text{S.I.} &= \text{pH} - \text{pH}_s \\ \text{where S.I.} &= \text{saturation index} \\ \text{pH} &= \text{pH of water} \\ \text{pH}_s &= \text{a function of calcium content} \\ &\quad \text{and alkalinity} \end{aligned}$$

The method of determining S.I. is described more fully by Langelier (1946). Saturation indices for all wells with available data were calculated and are also listed in Table 4. Because the above method provides for the calculation of S.I. at 25°C only, whereas most ground waters are about 10°C, the S.I. values can be used only to compare relative corrosiveness of waters; the lower the value the more corrosive the water. Large negative values are generally indicative of corrosive waters, while waters with positive values are usually considered non-corrosive.

TABLE 5. THE EFFECTS OF PLUMBING SYSTEMS ON TRACE METAL CONTENTS IN DOMESTIC SUPPLIES

Sample No.	Date	pH	Aluminum	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Zinc	S.I.* @25°C
		Field	mg/L Al	mg/L As	mg/L Ba	mg/L Cd	mg/L Cr	mg/L Cu	mg/L Pb	mg/L Zn	
Drinking Water Objectives (mg/L)			NA	0.05	1.0	0.01	0.05	1.0	0.05	5.0	
9. I	Nov.18/81	5.9	.031	< .001	.040	.0005	< .001	.210	.030	.110	
II			.048	< .001	.010	< .0001	.001	.010	< .003	.008	
III	(copper plumbing)		.050	< .001	.035	.0003	.001	2.600	.081	.170	
IV			.084	< .001	.047	< .0001	< .001	.082	< .003	.052	-3.4
10. I	Nov.19/81	5.8	.110	< .001	.041	.0008	.002	8.900	.210	.330	
II			.072	< .001	.043	.0004	.001	.800	.024	.450	
III	(copper plumbing)		.920	< .001	.054	.0011	.006	17.000	.120	3.600	
IV			.400	< .001	.048	.0004	.003	.840	.013	.260	-2.4
32. I	Nov.19/81	8.5	.019	< .001	.005	< .0001	.003	.067	< .003	.044	
II			.021	< .001	.006	< .0001	.002	.019	< .003	.053	
III	(copper plumbing)		.004	< .001	.005	< .0001	.002	.034	< .003	.098	
IV			.007	< .001	.005	< .0001	.002	.003	< .003	.080	+0.1
34. I	Nov. 19/81	5.1	1.200	< .001	.130	.0008	.006	4.500	.210	2.700	
II			1.100	< .001	.100	.0007	.005	.390	.120	.360	
III	(copper plumbing)		1.100	< .001	.120	.0007	.006	2.600	.073	1.300	
IV			1.600	< .001	.130	.0007	.006	.058	.003	.740	N.A.

\* S.I. = Langelier Saturation Index; see text on page 23

Legend: I Hot Unflushed  
 II Hot Flushed  
 III Cold Unflushed  
 IV Cold Flushed

TABLE 5. Cont'd

Sample No.	Date	pH	Aluminum mg/L Al	Arsenic mg/L As	Barium mg/L Ba	Cadmium mg/L Cd	Chromium mg/L Cr	Copper mg/L Cu	Lead mg/L Pb	Zinc mg/L Zn	S.I.* @25°C
Drinking Water Objectives (mg/L)			NA	0.05	1.0	0.01	0.05	1.0	0.05	5.0	
41.I	Nov. 18/81	5.4	.950	< .001	.060	.0003	.002	1.600	.064	.540	
II			.410	< .001	.056	.0002	.001	.082	.013	.055	
III	(copper plumbing)		.340	< .001	.059	.0007	.001	1.400	1.400	.210	
IV			.470	< .001	.058	.0002	.001	.015	.017	.030	-3.7
47.I	Nov. 18/81	5.0	.410	< .001	.310	.0008	.003	.740	.140	.480	
II			.370	< .001	.320	.0008	.003	.260	.037	.250	
III	(plastic plumbing?)		.880	< .001	.350	.0009	.003	.200	.180	.900	
IV			.960	< .001	.370	.0008	.003	.032	.012	.520	N.A.
62.I	Nov. 18/81	6.0	.160	< .001	.022	.0004	.002	.490	.075	3.300	
II			.045	< .001	.022	.0003	< .001	.110	.007	.030	
III	(copper plumbing)		.045	< .001	.020	.0003	< .001	.590	.130	.081	
IV			.043	< .001	.020	.0004	< .001	.015	.006	.006	-3.1
85.I	Nov. 18/81	5.8	.085	< .001	.036	.0009	.002	2.400	.041	2.500	
II			.064	< .001	.036	.0006	.001	.640	.020	.150	
III	(copper plumbing)		.090	< .001	.035	.0005	.004	3.700	.039	2.600	
IV			.090	< .001	.033	.0003	.003	.520	.010	.067	-2.6

\* S.I. = Langelier Saturation Index; see text on page 23

Legend: I Hot Unflushed  
 II Hot Flushed  
 III Cold Unflushed  
 IV Cold Flushed

TABLE 5. Cont'd

Sample No.	Date	pH	Aluminum	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Zinc	S.I.* @25°C
		Field	mg/L Al	mg/L As	mg/L Ba	mg/L Cd	mg/L Cr	mg/L Cu	mg/L Pb	mg/L Zn	
Drinking Water Objectives (mg/L)			NA	0.05	1.0	0.01	0.05	1.0	0.05	5.0	
99.I	Nov. 19/81	6.3	.053	< .001	.013	.0003	.002	2.130	.006	.280	
II			.048	< .001	.016	.0004	.002	.340	< .003	.270	
III	(copper plumbing)		.063	< .001	.014	.0002	.002	4.700	.044	.670	
IV			.080	< .001	.015	.0017	.006	.400	.010	.200	-

\* S.I. = Langelier Saturation Index; see text on page 23

Legend: I Hot Unflushed  
 II Hot Flushed  
 III Cold Unflushed  
 IV Cold Flushed

A summary of data in Table 5 indicates the following points:

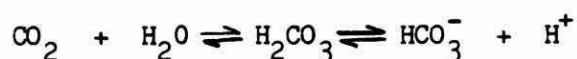
- aluminum levels at the nine sites vary widely, with the highest levels in excess of 1 mg/L found in sample 34. The high levels at site 34 are well above the assumed background levels of generally less than 0.1 mg/L shown in Table 4. Since the plumbing system at site 34 consists of copper, a source of large amounts of aluminum from plumbing is not apparent. The fact that often the cold, flushed samples (also assumed to represent background levels) have highest aluminum levels, suggests that aluminum is not leached from plumbing systems;
- no variations in arsenic are noted in any of the samples;
- although there are variations from site to site in barium, cadmium and chromium, generally small variations occur among the four samples taken at each site; this signifies that plumbing systems do not appear to affect these parameters;
- copper levels exceed the drinking water objective of 1.0 mg/L in one or more samples at six of the nine sites; a total of 11 samples have copper levels above 1.0 mg/L, with the highest level of 17.0 mg/L found in the cold, unflushed sample at site 10; all flushed samples, whether obtained from cold or hot water plumbing systems, have copper levels less than 1 mg/L;
- 12 samples have lead levels in excess of the drinking water objective of 0.05 mg/L; the highest levels are found most often in the unflushed samples, suggesting that copper plumbing systems can be sources of considerable amounts of lead;
- although zinc levels in some unflushed samples are fairly high compared to assumed background levels, none exceed the drinking water objective of 5.0 mg/L; six samples exceed 1.0 mg/L, and the highest value is 3.6 mg/L found in the unflushed, cold water sample at site 10; the highest zinc values are usually found in the unflushed samples and often the levels in cold, unflushed samples exceed those in hot unflushed samples;

- as expected, the lowest levels of trace metals occur in samples at site 32 where the pH of 8.5 is well above the pH values in samples at the other eight sites; however, there are no clear correlations of pH and trace metal contents at the nine sites. In examining the copper levels in the unflushed and flushed samples at site 32, it appears that there is some leaching of copper in the unflushed pipes;
- although the owner at site 47 has indicated that the domestic plumbing system is made up totally of plastic piping, the higher levels of copper, lead and zinc in the unflushed samples suggest that the system contains some metal piping.

Based on the above general observations, it appears that copper, lead and zinc are most prominently leached by waters that have a pH generally less than 6. Of the three parameters, copper and lead levels may often exceed drinking water objectives in waters left standing in copper pipes for a period of time. Flushing of the pipes usually reduces the concentrations of both to below the objectives and is one means of reducing excessive copper and lead levels in water before it is used for domestic purposes. It is significant to note that the objective of 1.0 mg/L for copper is based on taste rather than toxicity, while the lead level of 0.05 mg/L is set in consideration of health effects from long-term consumption.

#### Carbon Dioxide/pH Relationship

The presence of dissolved CO<sub>2</sub> in ground water can be an important contributor of carbonic acid (H<sub>2</sub>CO<sub>3</sub>), which in turn can contribute to low ground-water pH values and low buffering capacities (Freeze and Cherry, 1979). The basic equation of CO<sub>2</sub> equilibria in water is:





The removal of  $\text{CO}_2$  gas from solution would drive this equation to the left, thus also reducing  $\text{H}^+$ . The accepted methods for  $\text{CO}_2$  removal include boiling of the sample and purging the sample with nitrogen gas.

To obtain some idea of the relationship of  $\text{CO}_2$  content and pH in the inventory study to date, two separate sets of samples were taken for  $\text{CO}_2$  determinations. A total of 29 samples were taken in the Muskoka and Sudbury areas and both boiling and nitrogen purge methods were used to remove the  $\text{CO}_2$ , as indicated on Figure 7. The samples were taken from house taps and had to be delivered to the Ministry lab at Dorset within 24 hours.

Figure 7 indicates the changes in pH with  $\text{CO}_2$  removal by boiling (Nov/81), and by boiling and nitrogen purge (Jan/82). In all but one of the samples (sample 34) the pH values increased with  $\text{CO}_2$  removal. The nitrogen purge method showed generally smaller pH increases and is thought by chemists to be a better method of  $\text{CO}_2$  removal.

The increases in pHs are variable, but generally the higher the initial pH the smaller the increase due to  $\text{CO}_2$  removal. The pH of sample 34 decreased from 4.97 to 4.70 and this is attributed to lab procedure rather than to changes brought about by chemistry. It is likely that the low pH in sample 34 is due mainly to a mineral acid and not to the presence of  $\text{CO}_2$ .

The limited data to date on the  $\text{CO}_2$ /pH relationship suggests that dissolved  $\text{CO}_2$  is an important factor in the low ground-water pH values found in the Muskoka-Haliburton and Sudbury areas. Future work in this subject will continue and involve obtaining a larger data set in order to standardize lab procedures over the total observed range of ground-water pH values. Subsequently, the determination of  $\text{CO}_2$  content and its effect on low-pH ground-water samples in future inventories will be carried out routinely to provide a reliable data set for answering the ultimate question of the effects of acid precipitation on ground water.

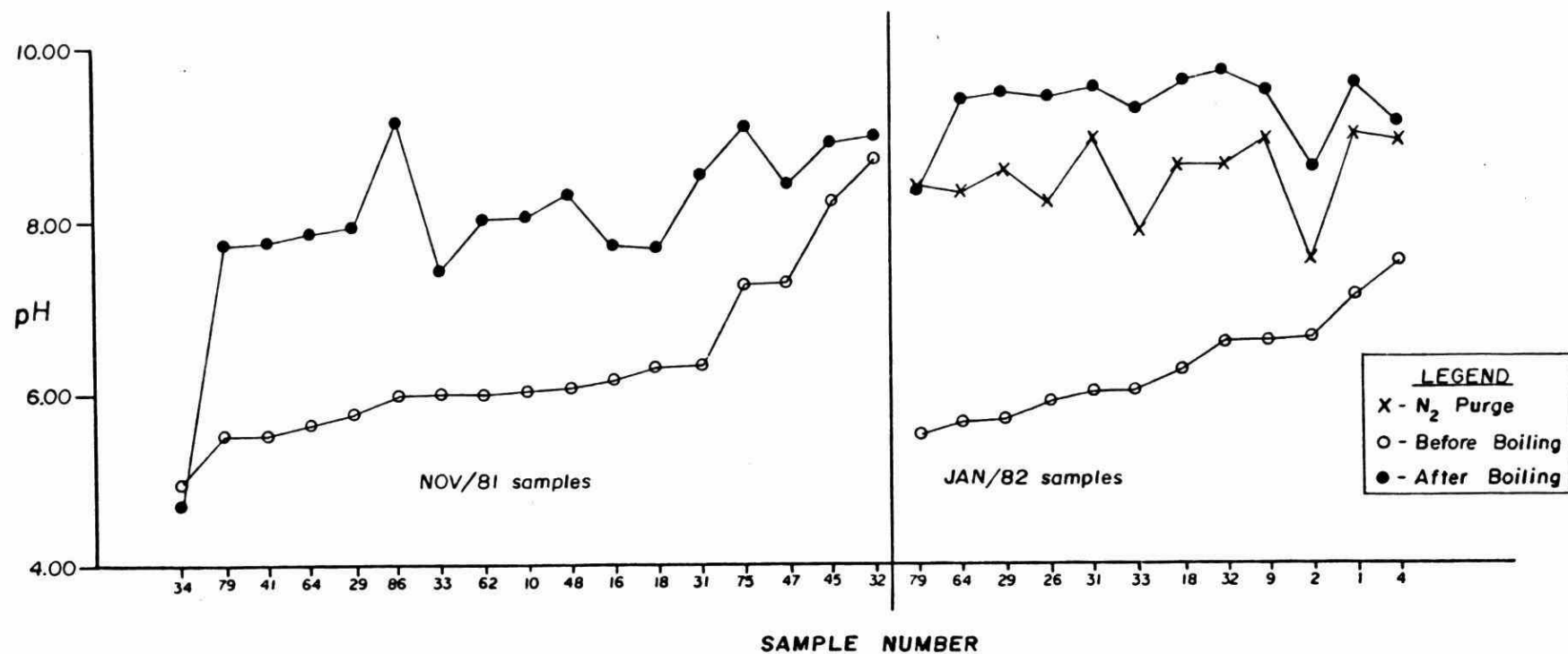


FIGURE 7. CHANGES IN GROUND-WATER pH VALUES WITH THE REMOVAL OF CO<sub>2</sub>

## Conclusions

The sampling and analysis of 123 domestic water well sites in 1981 in the Sudbury area indicated a range of water quality in which 6 sites (5%) had pH values equal to or less than 6.0, 54 sites (43%) had pH values between 6.0 and 7.0, and 65 sites (52%) had pH values equal to or greater than 7.0. Only one site had a field pH value of less than 5 (pH = 4.8). However, evidence in this study and on-going pH monitoring in the Muskoka area suggests that ground-water pH values may vary considerably during the year and the above results should be considered representative of one-time sampling only.

As found in the Muskoka-Haliburton study (Sibul and Vallery, 1982), variations in ground-water pH values could not be readily explained by variations in geology or hydrogeology apparent from physical land features. However, as was evident in the Muskoka-Haliburton area, low-pH values in the Sudbury area often occur in shallow overburden wells completed most often in sand and/or gravel. Any correlations appear to be complex and are possibly overshadowed by the dependence of pH on carbon dioxide dissolved in ground water.

Of importance in the Sudbury area study are the corrosive effects of low-pH waters on common domestic plumbing systems. Corrosive waters were found in a considerable number of wells and some of the waters left standing in domestic plumbing systems contained levels of copper and lead that exceeded the respective drinking water objectives. Because levels of both metals were usually reduced below the objectives by flushing of tap water, it appears important that waters from private systems with a pH of less than about 6 used for domestic consumption be taken only from flushed systems. One to two minutes of flushing may be adequate for this purpose.

An investigation of the effects of CO<sub>2</sub> content in ground water and its relationship to water pH was started. The preliminary results suggest that CO<sub>2</sub> content plays an important role in low ground-water pH values and sufficient data need to be gathered in further investigations to provide a statistically significant data base in northern Ontario.

Because of the apparent control that CO<sub>2</sub> has on the small number of low-pH ground waters tested so far, it would appear that acid precipitation has not affected ground water to a great extent in the areas studied to date. However, this may change in the future as suggested by ground-water data in Sweden, where in some areas, ground-water pH values attributed to acid precipitation are frequently less than 5 (Hultberg & Wenblad, 1980; Hultberg & Johansson, 1980). With basically similar geology, and if acid loading conditions remain at present levels, it is reasonable to expect in the future a greater degree of acidification of ground waters in Ontario due to acid precipitation. Consequently, future ground-water work should be directed towards establishing a sound data base on ground-water quality in the most susceptible areas in northern Ontario, towards understanding the factors that presently control that quality, and towards determining how continued acid loadings are likely to affect those factors and consequently ground-water quality with time. In addition, a larger emphasis should be placed in future inventories on seeking out wells likely to have low pH values, i.e., shallow wells in areas of surficial sand and gravel deposits.

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# APPENDIX

Tabulation of field conductivity, pH and water temperature for all samples in the Sudbury area, 1981.

Sample No.	Field Conductivity Corrected to 25°C (umhos/cm.)	Field pH	Water Temperature (°C)
1	-	7.7	17.5
2	-	7.7	16.0
3	-	7.6	20.0
4	-	8.2	15.0
5	235.	7.9	10.0
6	105.	7.2	15.0
7	601.	7.4	18.0
8	335.	6.3	18.0
9	167.	5.9	20.0
10	295.	5.9	16.0
11	458.	6.8	16.0
12	374.	6.9	16.0
13	308.	6.4	15.0
14	283.	8.1	15.0
15	431.	7.3	15.0
16	406.	7.7	15.0
17	1058.	7.1	15.0
18	731.	7.3	14.0
19	462.	7.7	18.0
20	579.	6.9	13.0
21	531.	7.6	17.0
22	522.	7.2	20.0
23	706.	7.0	14.0
24	151.	8.2	14.0
25	332.	8.1	15.0
26	347.	7.0	13.0
27	897.	6.5	10.0
28	1078.	7.0	11.0
29	237.	6.3	12.0
30	348.	6.7	17.0
31	146.	6.8	23.0
32	118.	8.8	12.0
33 (Capreol)	209.	7.2	15.0
34(1)	270.	4.8	12.0
34(2)	197.	4.9	12.0
35	260.	7.0	18.0
36	900.	7.3	13.0
37	499.	7.4	11.0
38	651.	7.2	12.0
39	123.	6.7	8.0
40	124.	6.5	17.0
41	180.	5.7	13.0
42	277.	7.6	18.0
43	355.	5.3	12.0
44	578.	7.3	17.0
45	295.	8.3	15.0

continuation

Sample No.	Field Conductivity Corrected to 25°C (umhos/cm.)	Field pH	Water Temperature (°C)
46	984.	7.3	15.0
47	87.	6.1	18.0
48	332.	6.9	15.0
49	122.	6.6	13.0
50	193.	6.8	16.0
51	391.	7.5	14.0
52	520.	7.4	12.0
53	325.	7.3	16.0
54	170.	6.5	22.0
55	602.	7.3	17.0
56	81.	5.9	18.0
57	615.	7.1	15.0
58	332.	7.4	15.0
59	602.	6.8	17.0
60	124.	6.7	19.0
61	542.	6.6	16.0
62	135.	6.0	15.0
63	220.	6.7	19.0
64	315.	8.1	13.0
65	470.	7.8	16.0
66	861.	7.0	15.0
67	635.	7.4	18.0
68	472.	7.8	17.0
69	2410.	7.2	16.0
70(1)	3465.	6.6	18.0
70(2)	1386.	6.8	14.0
71	384.	7.5	17.0
72	271.	7.3	19.0
73	155.	6.5	20.0
74	145.	6.7	12.0
75	578.	7.3	15.0
76	252.	6.4	14.0
77	844.	7.2	16.0
79	380.	7.0	16.0
80	199.	7.1	13.0
81	90.	7.4	13.0
82	448.	8.3	7.0
83	297.	7.6	11.0
84	101.	6.7	14.0
85	303.	6.1	12.0
86	201.	6.9	17.0
87	329.	6.7	12.0
88	317.	7.1	10.0
89	99.	7.2	9.0
90	542.	7.6	14.0
91	334.	6.4	14.0
92	209.	8.1	15.0
93	461.	7.6	12.0
94	329.	7.3	12.0

continuation

Sample No.	Field Conductivity Corrected to 25°C (umhos/cm.)	Field pH	Water Temperature (°C)
95	514.	6.3	13.0
96	154.	6.5	13.0
97	257.	6.3	13.0
98	277.	6.7	14.0
99	197.	6.2	12.0
100 (Capreol)	189.	6.7	14.0
101	125.	6.9	12.0
102 (Hanmer)	141.	7.4	15.0
103	127.	6.6	18.0
104	238.	7.0	13.0
105	485.	7.5	11.0
106	386.	6.6	13.0
107	128.	6.3	11.0
108	250.	7.6	12.0
109	277.	7.0	14.0
110	526.	7.1	12.0
111	401.	6.8	17.0
112	76.	6.9	14.0
113	72.	6.3	8.0
114	652.	7.3	21.0
115	882.	7.2	14.0
116	567.	7.2	14.0
118	90.	7.3	7.0
119	377.	6.2	11.0
120	218.	7.3	17.0
121	364.	8.1	11.0
122	243.	6.4	11.0
123	389.	7.8	17.0
124	418.	7.7	11.0
125	277.	7.6	14.0
126	178.	8.2	12.0
127	425.	7.5	17.0
128	462.	6.9	18.0



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